<u>PhD thesis – Laser spectroscopy of a trapped single-ion on a chip</u>

The proposed PhD subject will be conducted within FEMTO-ST Time and Frequency department (TF dpt). The context of this thesis is a single-ion, compact optical atomic clock project.

The candidate will join the Oscillators, Clocks, Metrology and Systems (OHMS) team of the TF dpt. OHMS research is focused on time and frequency metrology, with the development and characterization of ultra-stable oscillators (quartz, sapphire, lasers…) and atomic clocks (microwave vapor cell clocks, single-ion clock, superradiant laser). The OHMS team is intertionally renowned in the TF field.

The SI second is the physical unit realized with the best accuracy. This technical prowess is due to atomic clocks, which have experienced a constant technical progress for the past 50 years. Today's best atomic clocks are based on ultra-stable lasers referenced to an optical energy transition in a laser-cooled, trapped atomic standard.

The TF dpt has pioneered ultra-stable quartz and sapphire oscillators, and is developing frequency-stabilized lasers since 2012. The dpt has also been leading a European chip-scale atomic clock project. The development of a compact optical clock based on trapped Yb^+ single-ions started in 2014 within this context.

The goal of the project is to develop an atomic clock with a reduced footprint (<500L) with an order of magnitude improvement compared to today's best commercial atomic clocks. This will be possible thanks to the use of a surface Paul trap. Using micro-fabricated RF electrodes under 250 V voltages, a chip generates a trapping potential located 500 µm above its surface. The chip is integrated to an ultra-high vacuum chamber ($<10^{-9}$ mbars) that also contains the Yb atoms source and grants optical access for fluorescence detection.

A prototype trap was used to successfully demonstrate single-ion trapping and laser cooling in June 2018, for the first time in Bourgogne Franche-Comté. A new trapping chip was designed and produced at the MIMENTO cleanroom facility, using DRIE on a SOI wafer. A fully operational laser setup was also developed and characterized, thanks to the equipment and signal analysis tools of the OSCILLATOR-IMP platform, which includes ultra-stable Fabry-Perot cavities and optical frequency combs.

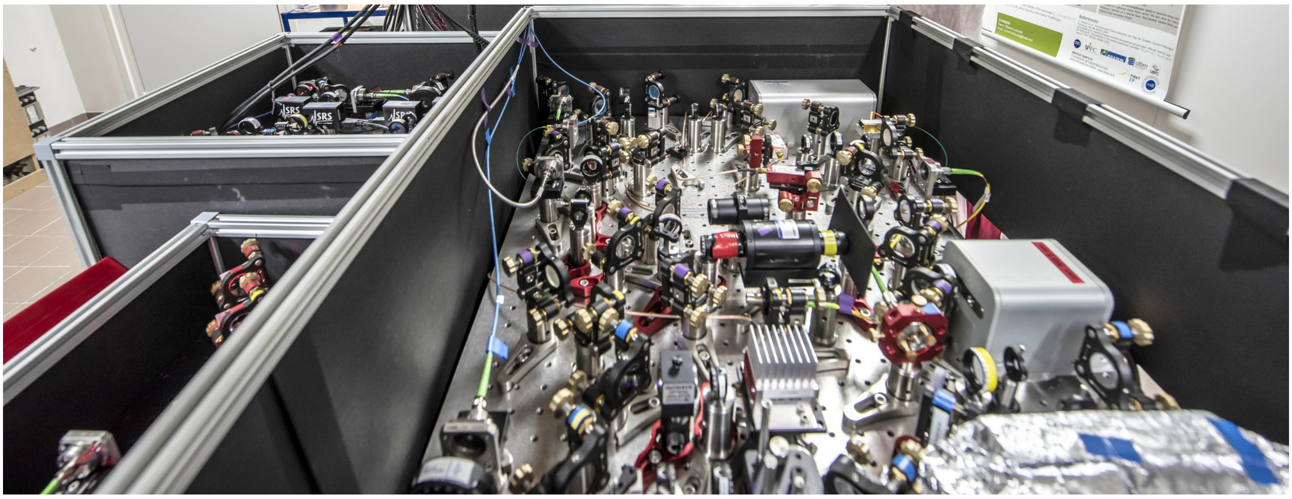

Fig. 1 : Banc optique de refroidissement et détection laser des ions Yb+

The PhD thesis will first be dedicated to the test of the micro-fabricated trapping chip (ions temperature, lifetime, heating rate, micro-motion reduction…). It will then turn to the laser spectroscopy of the Yb^+ quadrupole transition at 436 nm. A first analysis of the clock fractional frequency stability will finally be conducted. The study of Rabi, Ramsey and hyper-Ramsey spectroscopy sequences will also be considered.

The candidate will learn exceptional experimental methodology and know-how, in a high-level scientific environment. TF metrology requires an exquisite control of the experimental setup components. This theoretical and technical ability to master noise and signal analysis is of great help in many domains outside of TF metrology. In addition, the candidate will acquire skills in the ion trapping domain, which is not highly represented in France but starts to develop greatly internationally due to the rise of quantum information processing.

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